

DISC HAVING GROOVES AND PITS WITH DIFFERENT DEPTHS, AND METHOD FOR MANUFACTURING THE DISC

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This Application claims the benefit of Korean Application No. 00-30034, filed June 1, 2000 in the Korean Patent Office, the disclosure of which is incorporated herein by reference.

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0002] The present invention relates to an optical disc having grooves and pits with different depths, and an easy method of manufacturing a disc having grooves and pits with different depths using a stamper obtained by stamping from a master an even number of times.

2. Description of the Related Art

[0003] Rewritable, erasable and reproducible optical discs, such as digital versatile disc random access memory (DVD-RAM) and DVD-rewritable (RW), include grooves for recording and/or reproduction. The main difference between DVD-RAM and DVD-RW is in their recording regions. In particular, information can be written to both land and groove regions of a DVD-RAM, and the DVD-RAM has separated addresses formed as pits, such that desired information can be searched throughout the DVD-RAM by such physical units. In contrast, as for the DVD-RW, information can be written to only the groove region, and block addresses, instead of the pits of the DVD-RAM, are formed in the land region (i.e., land pre-pits). However, pits can also be formed in the land region of the DVD-RW when reproduction-only information, i.e., data for copy protection, is required.

[0004] The width and depth of the grooves in a DVD-RW are determined for excellent jitter characteristics without pits. An appropriate depth of the DVD-RW grooves is about 20-40 nm, which can be expressed as $\lambda/12n$, using the wavelength (λ) of a laser beam and the refractive index (n) of the disc. This groove depth of the DVD-RW is smaller than that of DVD-RAM, which is expressed as $\lambda/6n$. In case of the DVD-RW, if pits are formed to have the same depth as that of the grooves at $\lambda/12n$, the following problems occur.

[0005] As shown in FIG. 1, the pit depth for the DVD-RW can be determined based on the amplitude ratio of a reproduction signal. Referring to FIG. 1, the amplitude of a reproduction signal from pits was measured with respect to variations of pit depth in units of λ at a wavelength of 650 nm, a numerical aperture (NA) of 0.6, and a minimum mark length of $0.42 \mu\text{m}$, and then normalized with respect to a maximum amplitude of a reproduction signal, i.e., at the groove depth of a DVD-RW. The refractive index (n) of the disc is $1/5$. When a record mark length is $3T$ and $14T$, the amplitude ratio of each reproduction signal is m_1 and m_2 , which ranges between 0.2 and 0.3, at a pit depth of $\lambda/12n$, i.e., about 0.056λ . For a pit depth of $\lambda/4n$, i.e. about 0.167λ , the amplitude ratio of the reproduction signal is close to 1 at the point s .

[0006] As shown in FIG. 1, when the pit depth is equal to the groove depth at $\lambda/12n$, the signal level is 30% or less of the signal level at the pit depth of $\lambda/4n$. Such a pit signal level from the same pit and groove depth is unreliable. Therefore, a new disc having grooves and pits of different depths would improve pit reproduction signal levels.

[0007] A conventional method of manufacturing a disc having grooves and pits having different depths is illustrated in FIGS. 2A through 2H. As shown in FIG. 2A, a photoresist 103 is deposited over a glass master 100 and then exposed to cutting by laser beams having different powers $Pw1$ and $Pw2$. After a developing process, a pit region 104 and a groove region 105 having different depths h_1 and h_2

are obtained, as shown in FIG. 2B. Following this, the glass master 100 with the pit region 104 is etched using CF_4 gas (first etching step) such that the pit region 104 become deeper as shown in FIG. 2C.

[0008] As shown in FIG. 2D, the groove region 105 is exposed by ashing using O_3 gas, and then subjected to etching using CF_4 gas (second etching step). As a result, the pit region 104 and the groove regions 105 having different depths are formed, as shown in FIG. 2E. Then, as shown in FIG. 2F, the remaining photoresist 103 is removed by ashing (second ashing) using O_3 gas, thereby resulting in a master 106 having the pit region 104 with a depth s_1 and the groove region 105 with a depth s_2 , wherein the depth s_1 is larger than the depth s_2 .

[0009] A thin film is deposited over the master 106 with the pit region 104 and the groove region 105 by sputtering, as shown in FIG. 2G. Then, a stamper 110 is stamped from the master 106, wherein the stamper 110 has an inverse shape to that of the master 106, as shown in FIG. 2H. The stamper 110 is used to manufacture a substrate having pits and grooves with different depths by injection molding. Here, the bumps and recessions of the master 106 are printed as recessions and bumps in the stamper 110, and the substrate molded from the stamper 110 has the same shape as the master 106.

[0010] According to the conventional disc manufacturing process, the etching is performed twice, so that the entire process is complicated with low yield. Further, because the conventional disc manufacturing process uses only one stamper, the photoresist should be etched. In addition, the manufacturing cost is high.

SUMMARY OF THE INVENTION

[0011] To solve the above problems, it is an object of the present invention to provide a new disc using only grooves as recording/reproduction regions and also having a reliable or an optimum signal level from both a pit region, such as a

reproduction-only pit region (hereinafter referred to as pits) and the groove regions. In particular, it is an object of the present invention to provide a new disk having grooves and pits of different depths, for example, pits deeper than grooves, thereby improving reproduction signal level of the pits.

[0012] Therefore, the present invention can provide, for example, a DVD-RW disc having a reliable or an optimum signal level from both reproduction-only pit regions and groove regions.

[0013] It is also an object of the present invention to provide a new method of manufacturing of a disc having pits and grooves of different depths. In particular, it is an object of the present invention to provide a new method of forming grooves and pits having different depths by just cutting using laser beams with different power levels.

[0014] Therefore, the present invention provides a new method to manufacture rewriteable discs, such as DVD-RAM and DVD-RW, having grooves and pits with different depths. In particular, the discs can be DVD-RW or DVD-RAM or any other disc requiring grooves and pits of different depths.

[0015] Additional objects and advantages of the invention will be set forth in part in the description which follows and, in part, will be obvious from the description, or may be learned by practice of the invention.

[0016] The above objectives are attained by providing a disc having grooves and pits with different depths, the grooves having record marks for information recording, the disc comprising a first land having land pre-pits for address signals, the land pre-pits spaced a predetermined distance apart along the track direction of the disc; and a second land having the pits for reproduction-only, wherein the disc satisfies the conditions:

$$\lambda / 8n \leq d_3 \leq \lambda / 5n$$

where d_3 is a difference in depths between the grooves and the pits, λ is the wavelength of a light source, and n is the refractive index of the disc.

[0017] According to another aspect of the present invention, there is provided a method of manufacturing a disc having grooves and pits with different depths, the method comprising depositing photoresist over a glass master to have a thickness which is the same as the depth of pits of the disc to be manufactured; cutting a portion of the photoresist with a laser beam having a first power level to a depth d_1 to form a first land region, cutting a portion of the photoresist with a laser beam having a second power level higher than the first power level to a depth d_2 to form a second land, and developing the photoresist which has undergone the cutting of laser, thereby completing a master; stamping a father stamper having a groove region and a pit region from the master, the groove region and the pit region of the father stamper being inverse to those of the master; stamping a mother stamper from the father stamper, the shape of the mother stamper being inverse to the shape of the father stamper; and injection molding a disc substrate from the mother stamper, the disc substrate having grooves and pits corresponding to the groove region and the pit region of the mother stamper, respectively, wherein the depth d_1 of each of the grooves and the depth d_2 of each of the pits of the substrate are different.

BRIEF DESCRIPTION OF THE DRAWINGS

[0018] The above objects and advantages of the present invention will become more apparent by describing in detail preferred embodiments thereof with reference to the attached drawings in which:

FIG. 1 is a graph illustrating the amplitude ratio of a reproduction signal with respect to the pit depth of a disc;

FIGS. 2A through 2H are sectional views illustrating a conventional method for manufacturing a disc having grooves and pits with different depths;

FIG. 3 is a perspective view of a part of an embodiment of a disc having grooves and pits with different depths according to the present invention;

FIG. 4 is a sectional view taken along line IV-IV of FIG. 3;

FIG. 5 is a graph illustrating the sum signal level and tracking error signal level with respect to the groove depth;

FIG. 6 is a graph illustrating a push-pull signal level before recording, which is obtained from the results of FIG. 5; and

FIGS. 7A through 7E are sectional views illustrating a method of manufacturing a disc having grooves and pits with different depths.

DETAILED DESCRIPTION OF THE INVENTION

[0019] Reference will now be made in detail to the present preferred embodiments of the present invention, examples of which are illustrated in the accompanying drawings, wherein like reference numerals refer to the like elements throughout. The embodiments are described below in order to explain the present invention by referring to the figures.

[0020] An embodiment of a DVD-RW disc having grooves and pits with different depths according to the present invention is shown in FIGS. 3 and 4. The disc 40 includes a groove 10 having record marks 11, a first land 14 with land pre-pits 16 for address signals, which are spaced a predetermined distance apart along the track direction of the disc 40, and reproduction-only pits (simply referred to as pits) 15. A region having the pit 15 is referred to as a second land 17.

[0021] It is preferable that the groove 10 and the pit 15 both lie on the same base line 12 and the groove 10 and the pit 15 have different depths d_1 and d_2 , respectively. Alternatively, the tops of the first land 14 and the pit 15 both lie on the same line. The depths d_1 and d_2 of the groove 10 and the pit 15, respectively,

are determined such that both a push-pull signal PP for the groove 10 and a reproduction signal for the pit 15 have a reliable level up to a maximum level.

[0022] As shown in FIG. 1, the pit signal has a maximum level at a pit depth of $\lambda/4n$ or more. A sum signal level and a push-pull signal level (PP) equivalent to a tracking error signal level with respect to the groove depth are shown in FIG. 5. As shown in FIG. 5, the tracking error signal level is maximum at a groove depth of $\lambda/6n$, and the sum signal has a maximum level at a groove depth smaller than $\lambda/6n$.

[0023] The depths of grooves and pits of a disc are determined based on both the sum signal and the tracking error signal using formula (1) below.

$$PPb = \frac{[(I_a + I_b) - (I_c + I_d)]_{bc}}{[I_a + I_b + I_c + I_d]_{dc}} \dots (1)$$

[0024] In formula (1), "PPb" indicates a push-pull signal before recording, and is expressed as a ratio of the sum signal to the tracking error signal. The push-pull signal before recording PPb was calculated using the results of FIG. 5, and the calculated push-pull signal level before recording PPb is shown in FIG. 6. As shown in FIG. 6, the push-pull signal level is maximum at a groove depth of $\lambda/3.5n$ which is larger than $\lambda/6n$ at which the tracking error signal reaches a maximum level. In consideration of record and reproduction characteristics, the push-pull signal level before recording must be in the range of 0.22-0.44 under the DVD-RW specifications in the case of having the pits, as indicated by the points *a* and *b* in FIG. 6. Accordingly, the depth d_1 of the groove 10 is restricted within the range

between points a and b , i.e., in the range of $\lambda/30n - \lambda/8n$ and the depth d_2 of the pit 15 is $\lambda/4n$. This groove-to-pit depth relationship can be generalized using a difference d_3 between the depths d_1 and d_2 as follows:

$$\begin{aligned} (\lambda/4n - \lambda/30n) \leq d_3 \leq (\lambda/4n - \lambda/8n), \\ \lambda/8n \leq d_3 \leq \lambda/5n. \end{aligned}$$

...(2)

[0025] The depth d_1 of the groove 10, which satisfies the range of PPb level according to the DVD-RW specifications, can be determined, and then the range of depth d_2 of the pit 15 at which quality pit signal up to an optimal pit signal can be output is calculated using formula (2). In particular, a range of reliable or quality pit signals can be calculated by determining the depth d_1 of the groove 10, which satisfies the range of PPb level according to applicable DVD-RW specifications, and then the range of depth d_2 of the pit 15 at which the quality pit signal up to the optimal pit signal can be output is calculated using formula (3).

$$(3) \quad (\text{MaxPD} - \text{MinGD}) \leq d_3 \leq (\text{MaxPD} - \text{MaxGD})$$

[0026] In formula (3), MaxPD indicates a pit 15 depth at which a pit signal has a maximum level, MinGD indicates a minimum groove 10 depth under the DWD-RW specification and MaxGD indicates a maximum groove 10 depth under the DWD-RW specification. Formula (3) can, for example, also apply to DVD-RAM discs.

[0027] In order to manufacture a disc having grooves and pits having different depths according to the present invention, photoresist 20 is initially deposited over a

master glass 18 to have the thickness d_2 , which is equal to the depth d_2 of the pit 15, as shown in FIG. 7A. A first land region 25 of the photoresist 20 is cut to a depth d_1 by radiation of a laser beam 23 with a first power level, and a second land region 28 is cut to a depth d_2 by a laser beam 26 with a second level higher than the first power level. The first land region 25 and the second land region 28 will become the first land 14 and the second land 17, respectively, of the disc 40 described previously.

[0028] When the photoresist 20 is irradiated with a laser beam at the first time, tracks are formed in the opposite direction to the spiral direction of a target disc. This is because stamping from a master for the target disc is performed an even number of times, and then the last stamper among the resulting even number of stampers is used to manufacture the target disk.

[0029] After the laser cutting of the photoresist 20 is completed, the photoresist 20 is developed, so that a master having the first land region 25 with the depth d_1 and the second land region 28 with the depth d_2 is completed, as shown in FIG. 7B. Following this, a father stamper 33 is stamped from the master 30, as shown in FIG. 7C. Accordingly, the father stamper 33 has an inverse shape to that of the master 30. In other words, a first land region 25' projects and a groove region 27 results in between raised first land regions 25'. A second land region 28' projects and a pit region 29 results in between raised second land regions 28'.

[0030] Following this, a mother stamper 35, which has an inverse shape to that of the father stamper 33, but the same as the master 30, is stamped from the father master 33. In particular, as shown in FIG. 7D, the mother stamper 35 has a first land region 25'', a second land region 28'', a groove region 27' and a pit region 29', which have inverse shapes to those of the corresponding regions of the father stamper 33.

[0031] In manufacturing a stamper for use in injection molding a disc substrate, many disc substrates can be simultaneously manufactured using a plurality of stampers. In this way, if the plurality of stampers are stamped from the master 30, the photoresist 20 of the master 30, which is made into contact with each stamper, is possibly worn away, so that stampers with undesired shape can result. According to the present invention, a plurality of mother stampers 35 are stamped using the father stamper 33, thereby preserving the shape of master 30 by reducing wear on the master 30. Then, the mother stampers 35 are used in forming a disc 40 by injection molding.

[0032] As described above, when a disc is manufactured by injection molding using two stampers, i.e., the father stamper 33 and the mother stamper 35, as in the inventive disc manufacturing method, the father stamper 33 has the same pattern as that of the target disc 40 being molded, and the mother stamper 35 has the same pattern as that of the master 30. Thus, the pattern of the master 30 is inverse to that of the target disc 40. For this reason, unless on the photoresist 20 for the master 30 tracks are formed in the opposite direction to the spiral track of a target disc during the initial laser radiation, the target disc having a desired spiral track cannot be manufactured.

[0033] When a photoresist is irradiated with a laser beam to form a master, a predetermined period of wobbles, which serve as address signals, are formed in the first land region 25 of the photoresist 20. Accordingly, the wobbling frequencies of the groove regions 27 and 27' may vary and the carrier-to-noise (C/N) ratio of wobble signals may deteriorate.

[0034] These problems can be prevented if the wobbling frequency of the first land regions 25, 25' and 25'' can be coincided with that of the groove regions 27 and 27' by wobbling the first land regions 25, 25' and 25'' and the groove regions 27 and 27' such that they have the same phase. The wobbling frequencies and C/N of wobble signals in the groove 10 and the first land 14 (see FIG. 4) were measured

for a DVD-RW manufactured by the inventive method so as to check if the DVD-RW has problems. The results are shown in Table 1.

Table 1

	Groove	First land	Difference
Frequency	141.6 KHz	141.6 KHz	no difference
C/N (CL/NL)	38.3 dB (-26.0dBm/-64.3dBm)	37.0 dB (-27.3dBm/-64.3dBm)	1.3 dB

[0035] As shown in Table 1, there can be no difference in wobbling frequencies between the groove 10 and the first land 14. The difference in C/N between the groove 10 and the first land 14 is about 1.3 dB, which can be acceptable. The C/N in each of the groove 10 and the first land 14 is closed to 35 dB which is the standard requirement. In conclusion, the inventive disk manufacturing method causes few or no problems in wobble characteristics.

[0036] Another advantage of the inventive disc manufacturing method lies in that land pre-pits (LPPs) 16 spaced a predetermined distance apart along the track direction of the disc can be easily formed. In particular, in forming the LPPs 16 over the photoresist 20 with the cutting laser of a laser beam having a first power, the LPPs 16 can be easily formed by momentarily turning the laser off on a land pre-pit region (not shown) which will become the LPPs. Unlike a conventional method which needs additional cutting of laser to the first land 14 for the LPPs, the manufacturing process of the present invention is simplified.

[0037] As previously described, in the disc having grooves and pits with different depths according to the present invention, the depth of pits for reproduction-only, can be determined according to the PPb signal level which complies with the current DVD-RW specifications, such that the pit depth differs from the groove depth.

[0038] In addition, in the manufacture of a disc having grooves and pits with different depths according to the present invention, stampers are manufactured through an even number of stamping processes. Therefore, a disc, which complies with the current specification, can be manufactured using the even-number stamper and the disc can be manufactured without etching processes. The etching process can be obviated because according to the present invention discs are manufactured by at least two stampers, that is, a father stamper and a mother stamper. Land pre-pits can be formed by just turning the laser off, without any need for a separate laser cutting. Further, reproduction-only pits for a DVD-RW can be formed without etching. As a result, the entire manufacturing process can be simplified at low cost.

[0039] While this invention has been particularly shown and described with reference to preferred embodiments thereof, it will be understood by those skilled in the art that various changes in form and details may be made to the described embodiments without departing from the spirit and scope of the invention as defined by the appended claims.